Unit III: Solubility
Review problems (3.1-3.8)

1. Identify each of the following as ionic, partially ionic, or molecular substances:

a) $NaCl_{(aq)}$	ionic	$NaCl_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$
b) $CH_3CH_2CH_2COOH_{(aq)}$	partially ionic ~~molecular~~	$CH_3CH_2CH_2COOH_{(aq)} \rightarrow CH_3CH_2CH_2COO^-_{(aq)} + H^+_{(aq)}$
c) $CCl_{4(l)}$	molecular	$CCl_{4(l)} \rightarrow CCl_{4(aq)}$
d) $HNO_{3(aq)}$	ionic	$HNO_{3(aq)} \rightarrow H^+_{(aq)} + NO_3^-{}_{(aq)}$
e) $C_2H_{6(l)}$	molecular	$C_2H_{6(l)} \rightarrow C_2H_{6(aq)}$

organic acid → (b)

polyatomic ↳ (d)

(2 s.f.) ↳ (3.0M)

2. A chemistry stockroom contains a bottle of 12.0 M HCl. A teacher needs to make up 800.0 mL of a 3.0 M solution of HCl. What volume of the stock solution (12.0 M) does the teacher need to use?

$C_1 = 12.0M$
$C_2 = 3.0M$
$V_1 = ?$
$V_2 = 800.0mL$

$$C_1V_1 = C_2V_2$$
$$(12.0M)(V_1) = (3.0M)(800.0mL)$$
$$\frac{12(V_1)}{12} = \frac{2400}{12}$$
$$V_1 = 200\,mL = 2.0 \times 10^2\,mL \text{ or } \boxed{0.20\,L}$$

(2 s.f.)

3. If 25.0 mL of 0.90 M HCl is added to 125.0 mL of water, what is the final [HCl]?

$$C_1V_1 = C_2V_2$$

$C_1 = 0.90M$
$C_2 = ?$
$V_1 = 25.0mL$
$V_2 = 125mL + 25mL = 150.0mL$

$$C_2 = \frac{C_1V_1}{V_2} = \frac{(0.90M)(25.0mL)}{(150.0mL)}$$
$$[HCl] = \boxed{0.15M}$$

4. Calculate the $[Na^+]$ in a 0.55 M solution of sodium acetate. (Write the proper formula for sodium acetate first.)

$NaCH_3COO \longrightarrow Na^+ + CH_3COO^-$

0.55M — 0.55M — 0.55M ← 1:1 ratio

$[Na^+] = 0.55M$

(1 s.f.) from 200mL or 300mL

5. 200 mL of 0.500 M NaCl is mixed with 300 mL of 0.200 M $CaCl_2$. Calculate the final total $[Cl^-]$.

$NaCl \rightarrow Na^+ + Cl^-$

0.500M — 0.500M — 0.500M

$C_1V_1 = C_2V_2$

$[Cl^-]\ C_2 = \frac{C_1V_1}{V_2} = \frac{(0.500M)(0.200L)}{0.500L}$

$[Cl^-] = 0.200M$

$CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$

0.200M — 0.200M — 0.400M

$[Cl^-]C_2 = \frac{C_1V_1}{V_2} = \frac{(0.400M)(0.300L)}{(0.500L)}$

$[Cl^-] = 0.240M$

total $[Cl^-] = 0.200 + 0.240 = 0.440M$

1 sig fig = 0.4 M

6. Calculate the *molar solubility* of $BaCO_3$ in water.

$BaCO_{3(s)} \rightarrow Ba^{2+} + CO_3^{2-}$

1s — 1s — 1s

$K_{sp} = [Ba^{2+}][CO_3^{2-}] = 2.6\times10^{-9}$ ← look up in Ksp table.

$2.6\times10^{-9} = [Ba^{2+}][CO_3^{2-}]$

(molar solubility = equilibrium concentration @ saturation in mol/L)

1:1 ratio so each ion concentration is "s" → $2.6\times10^{-9} = (s)(s)$

$2.6\times10^{-9} = s^2$

$s = \sqrt{2.6\times10^{-9}} = 5.1\times10^{-5}$

$[BaCO_3] = 5.1\times10^{-5} M$

7. Calculate the number of grams of CaC_2O_4 which will dissolve in 1.5 L of water at 25 °C.

$CaC_2O_{4(s)} \longrightarrow Ca^{2+} + C_2O_4^{2-}$

(*calculate molar solubility of CaC_2O_4, then convert to g/1.5L*)

$K_{sp} = [Ca^{2+}][C_2O_4^{2-}] = 2.3\times10^{-9}$

$2.3\times10^{-9} = (s)(s)$

$2.3\times10^{-9} = s^2$

$s = \sqrt{2.3\times10^{-9}} = 4.8\times10^{-5}$

$[CaC_2O_4] = \frac{4.8\times10^{-5}\ mol}{L} \times \frac{128.1\ g}{1\ mol} \times \frac{1.5L}{}$

$= 9.2\times10^{-3}\ g\ CaC_2O_4$

(4 s.f) 8. The solubility of $CoCO_3$ in water is 1.189×10^{-3} grams per liter. Calculate the Ksp for $CoCO_3$.

$g \rightarrow mol \rightarrow M \rightarrow Ksp$

$$\frac{1.189\times10^{-3} g}{1 L} \times \frac{1 mol}{118.9 g} = 1.000\times10^{-5} mol/L$$ ← molar solubility

$$CoCO_{3(s)} \rightarrow Co^{2+} + CO_3^{2-}$$

$$Ksp = [Co^{2+}][CO_3^{2-}]$$ (1:1 molar ratio)

$$= (1.000\times10^{-5} M)(1.000\times10^{-5} M) = \boxed{1.000\times10^{-10}}$$

(4 s.f.) 9. It is found that 1.892×10^{-13} grams of the compound cadmium (II) sulphide (CdS) will dissolve in 350.0 mL of water to form a saturated solution. Using this data, calculate the value for the Ksp of CdS.

$$\frac{1.892\times10^{-13} g\ CdS}{0.3500 L} \times \frac{1 mol}{144.5 g} = 3.741\times10^{-15} M$$ (molar solubility)

$$CdS_{(s)} \rightarrow Cd^{2+} + S^{2-}$$

$3.741\times10^{-15} M \quad 3.741\times10^{-15} M \quad 3.741\times10^{-15} M$

(*convert g/mL to mol/L - molar solubility
- use molar solubility to calculate Ksp value using molar solubility*)
$g \rightarrow mol \rightarrow M \rightarrow Ksp$

$$Ksp = [Cd^{2+}][S^{2-}] =$$

$$Ksp = (3.741\times10^{-15})(3.741\times10^{-15}) = \boxed{1.399\times10^{-29}}$$

(4 s.f) 10. Calculate the maximum mass of $Mg(OH)_2$ which will dissolve in 150.0 mL of water. Show all of your steps clearly.

$$Mg(OH)_2 (s) \rightarrow Mg^{2+} + 2OH^-$$

s   s   2s

calculate molar solubility:

$$Ksp = [Mg^{2+}][OH^-]^2$$

$$5.6\times10^{-12} = (s)(2s)^2$$

$$5.6\times10^{-12} = 4s^3$$

$$s = \sqrt[3]{\frac{5.6\times10^{-12}}{4}} = 1.119\times10^{-4} M$$

convert to grams/0.150L:

$$mol = (M)(V)$$

$$= (1.119\times10^{-4} M)(0.1500 L)$$

$$= 1.678\times10^{-5} mol$$

$$mass = 1.678\times10^{-5} mol \times \frac{58.3 g}{1 mol}$$

$$= \boxed{9.783\times10^{-4} g}$$